# Diagnosing CAM MJO forecast biases using nuging: A DYNAMO MJO case study

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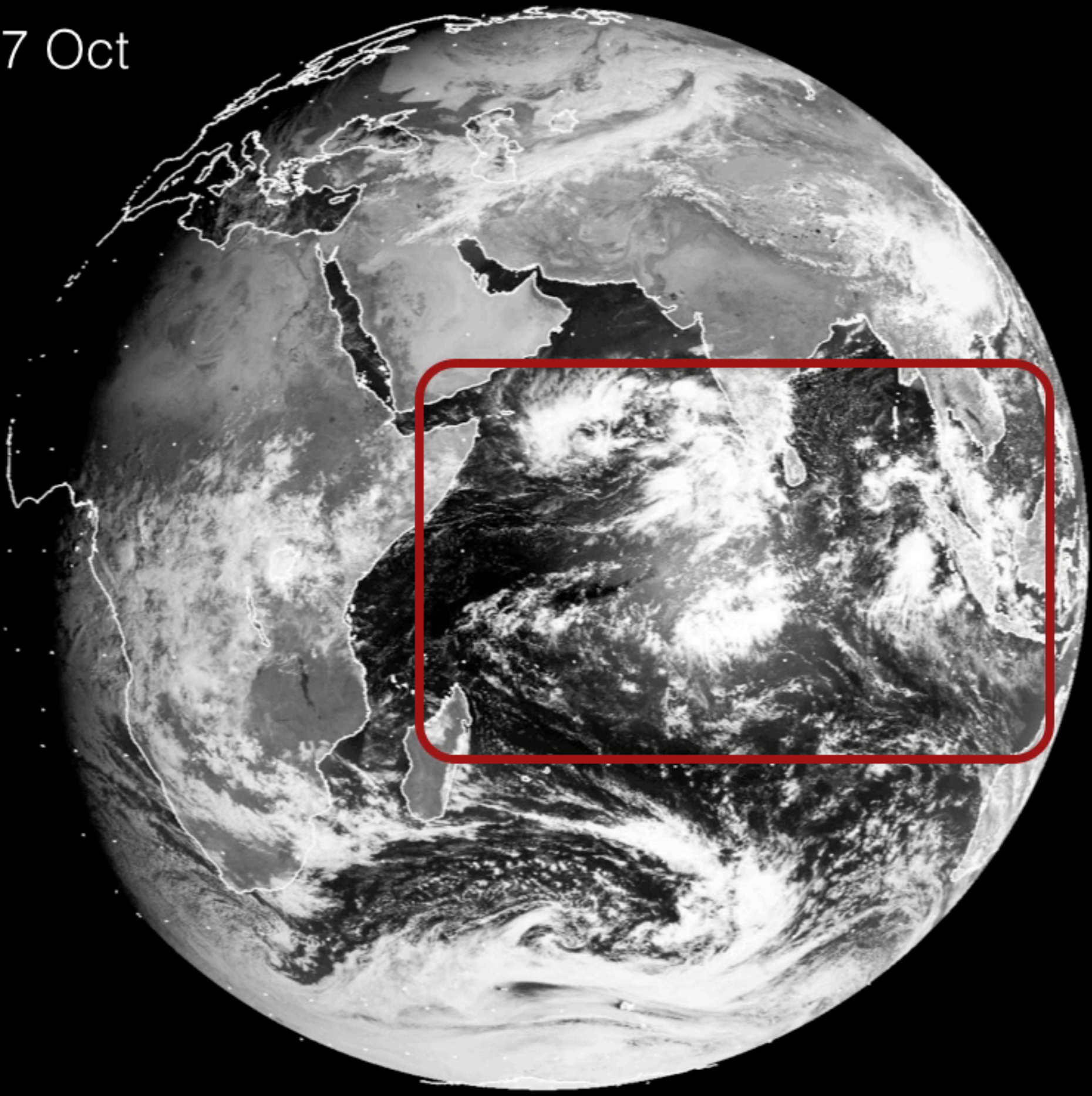
# Outline

- Diagnosing DYNAMO MJO forecasts using CAM
- Description of nudged MJO evolution in the model
- Results from analysis of nudging tendencies to diagnose biases in the evolving model solutions

27 Oct



Channel 1 received on 27/10/2011 at 600 from satellite NET7

# MJO Hindcast Experiment

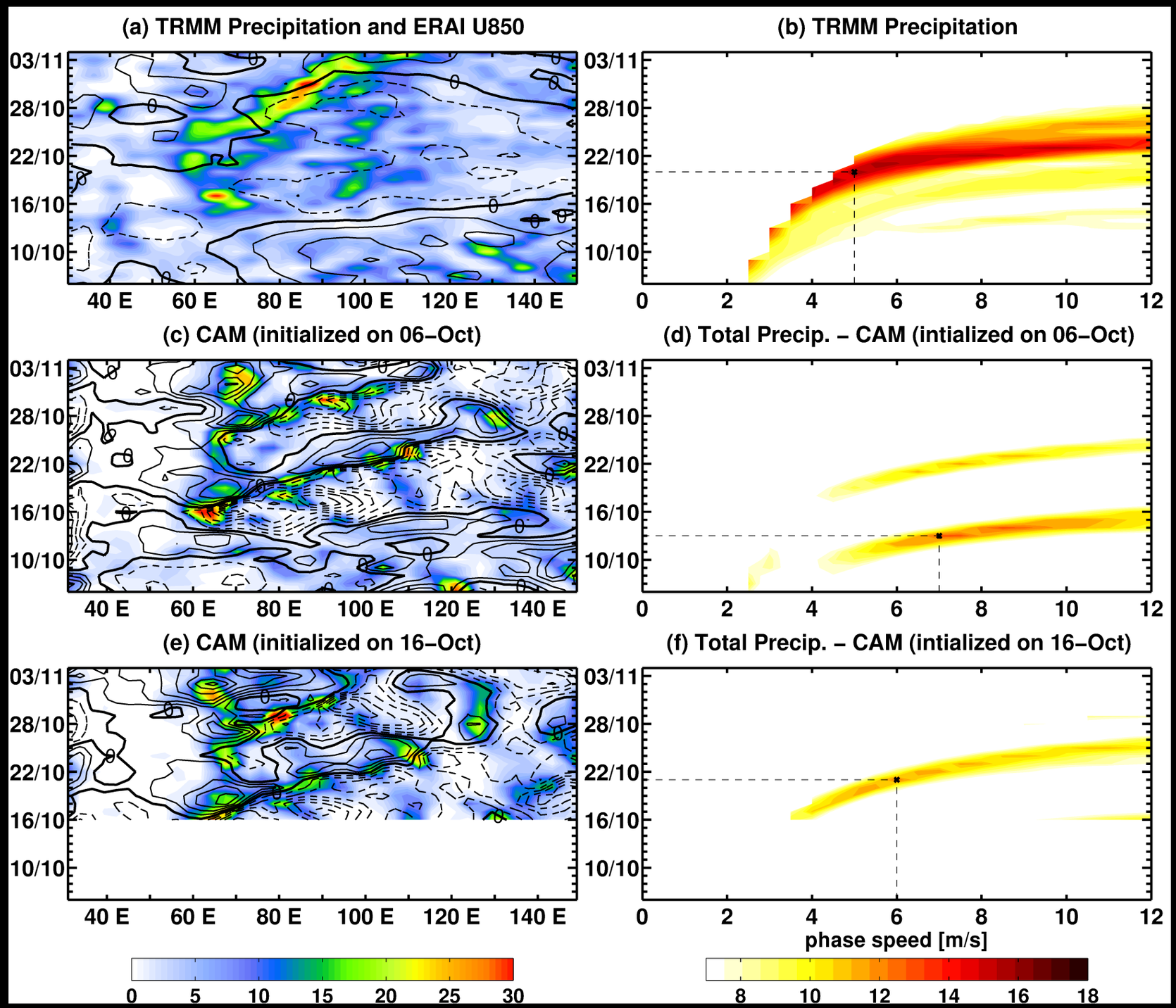
- Hindcasts are **initialized from ECMWF Reanalyses fields.**
- The model boundary is forced using Reanalysis SST.
- 26 levels in the vertical,
- ~2$^{o}$ horizontal resolution
- Revised Zhang-McFarlane convection scheme : based on free-tropospheric quasi-equilibrium.

# Precipitation and zonal winds

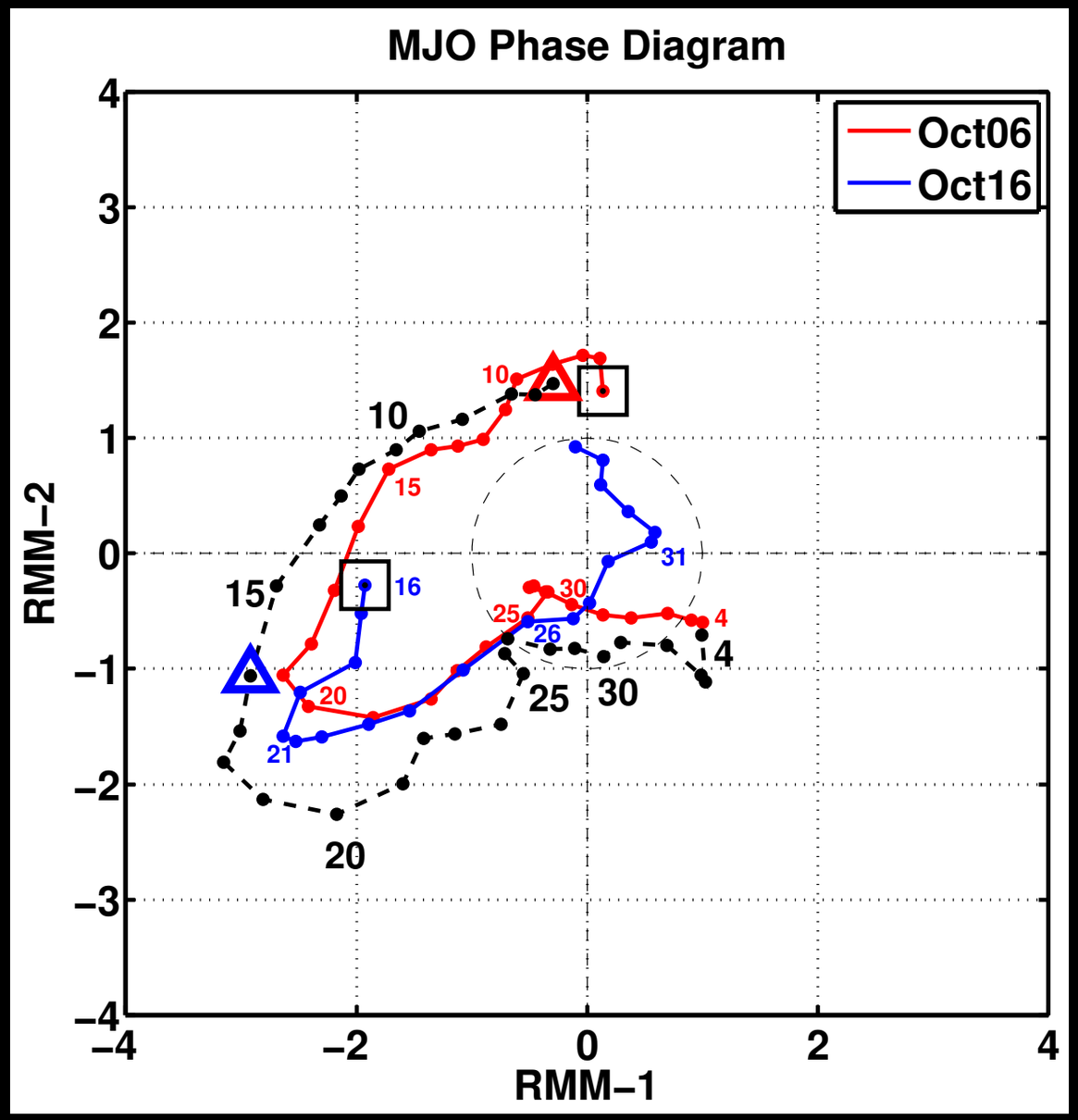
Observations

CAM Hindcast (6th Oct)

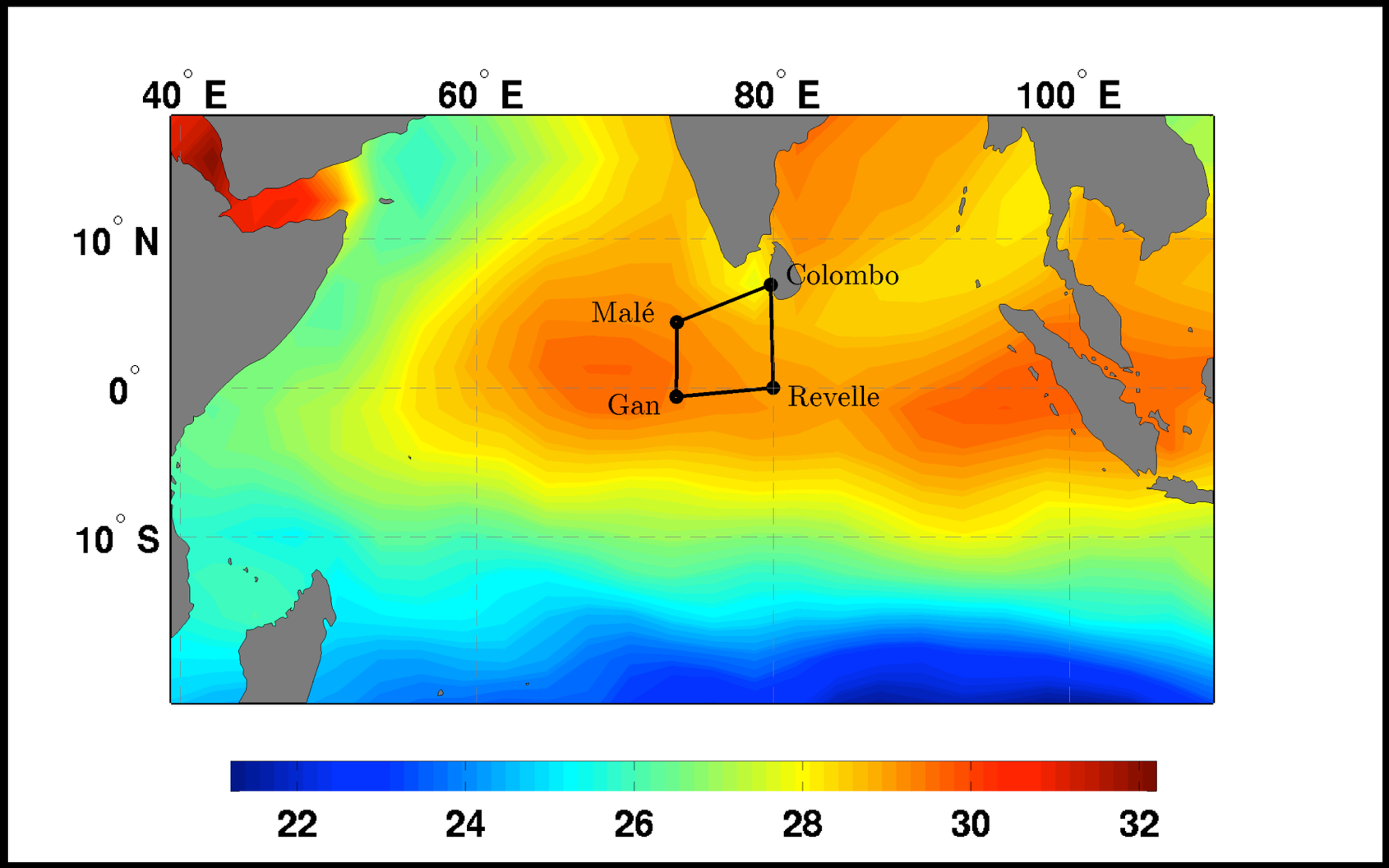
CAM Hindcast (16th Oct)



# Phase diagram



# Analysis Domain



# Hindcast Biases

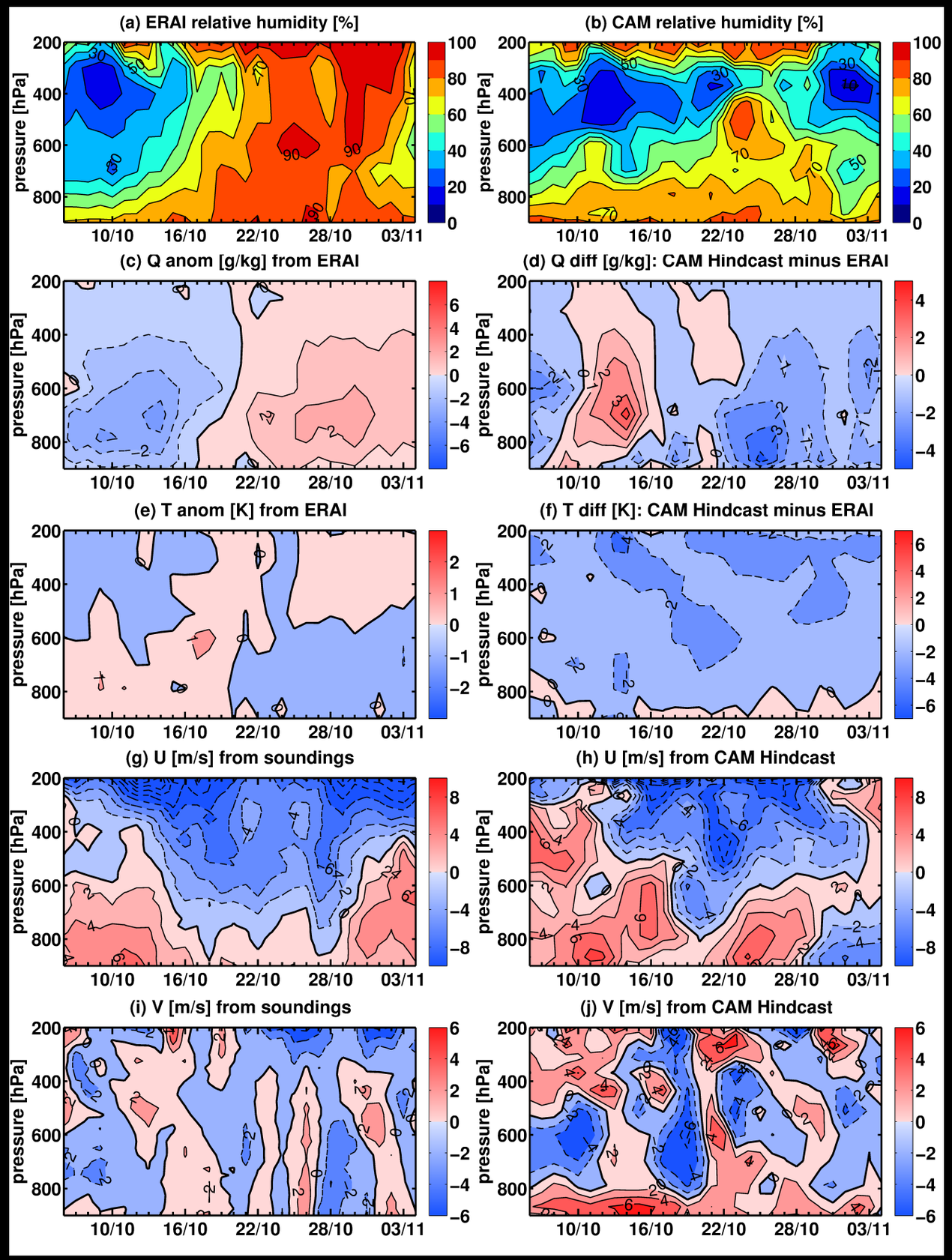
Rel. Hum.

Moisture anom.

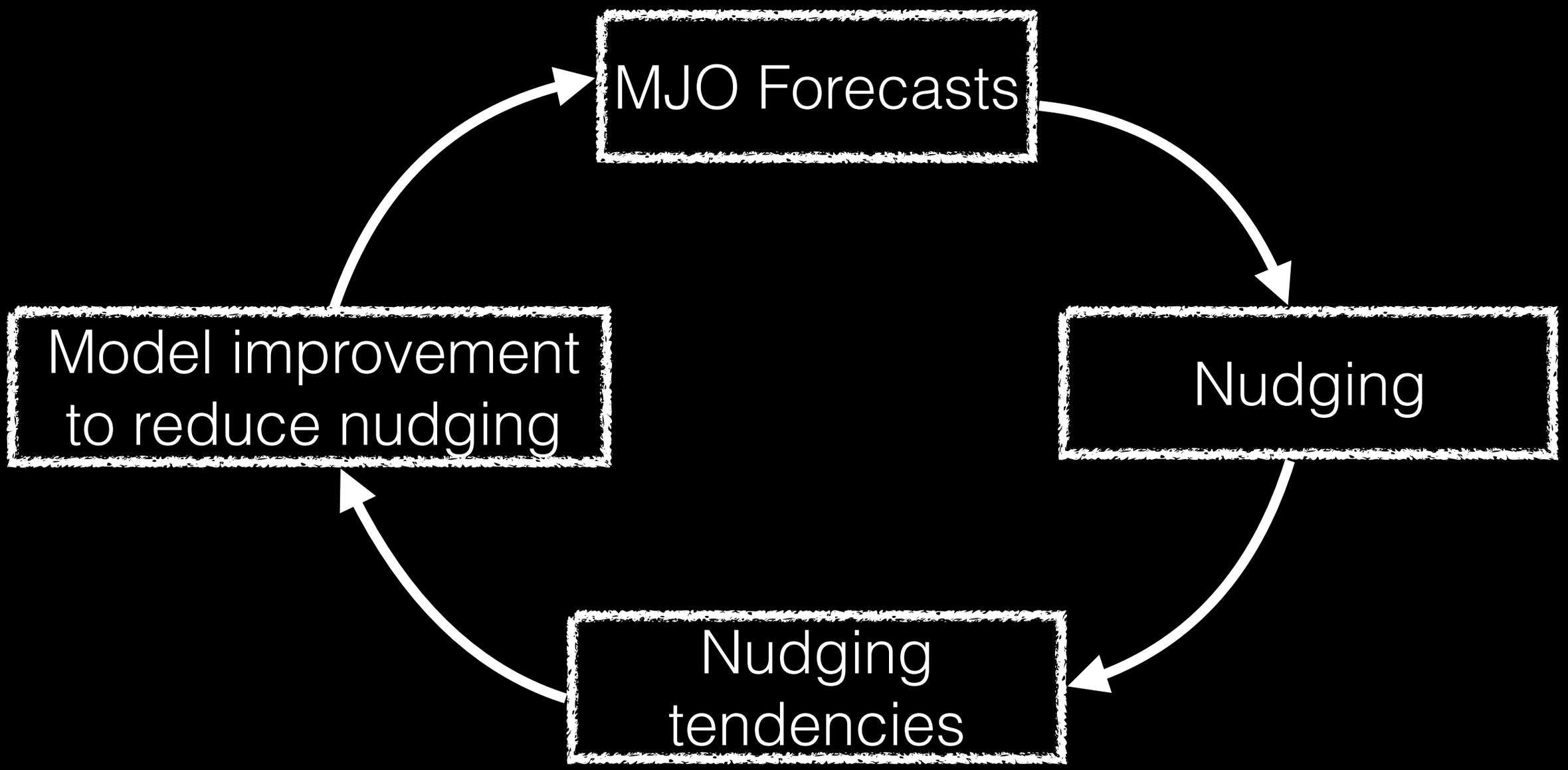
Temp. anom.

Zonal Wind

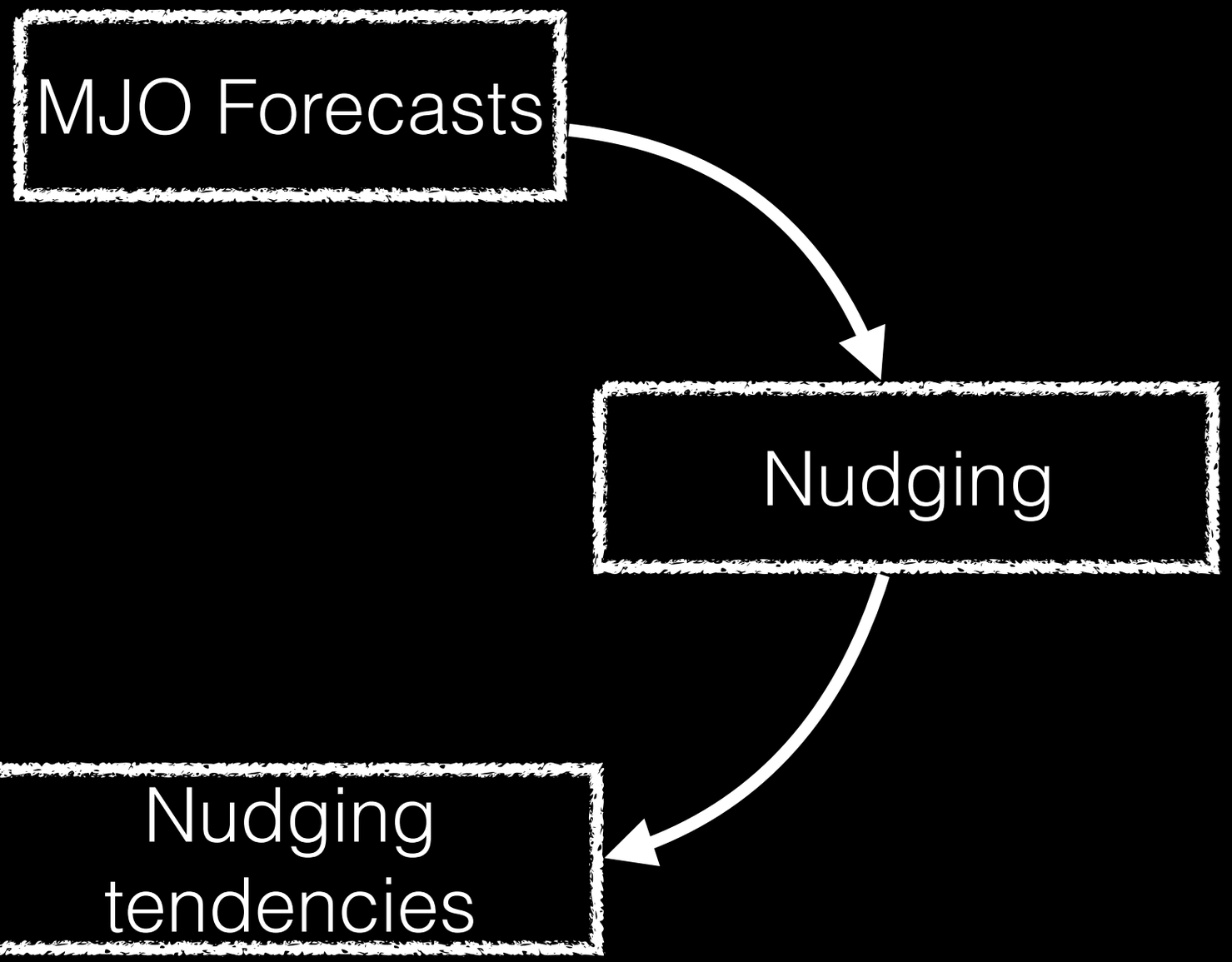
Merid. Wind



# Model Improvement



# Model Improvement



# Nudging

$$\left(\frac{\partial q}{\partial t}\right)_{\text{model}} = \left(\frac{\partial q}{\partial t}\right)_{dyn\_\text{model}} + \left(\frac{\partial q}{\partial t}\right)_{phys\_\text{model}} + \left(\frac{\partial q}{\partial t}\right)_{nudge}$$

$$\left(\frac{\partial q}{\partial t}\right)_{\text{obs}} = \left(\frac{\partial q}{\partial t}\right)_{dyn\_\text{obs}} + \left(\frac{\partial q}{\partial t}\right)_{phys\_\text{obs}}$$

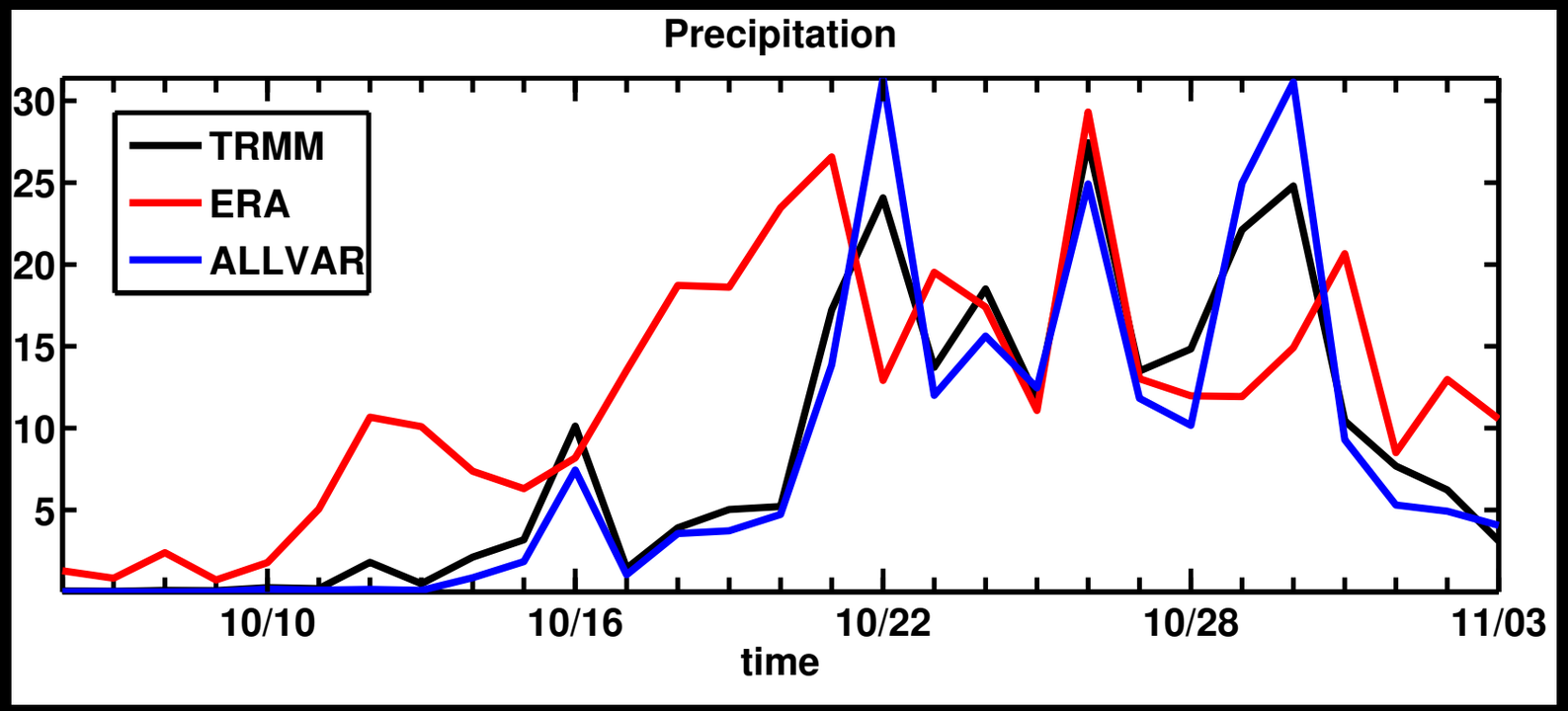
$$\left(\frac{\partial q}{\partial t}\right)_{nudge} = \left(\frac{\partial q}{\partial t}\right)_{phys\_\text{obs}} - \left(\frac{\partial q}{\partial t}\right)_{phys\_\text{model}}$$

- CAM nudged towards ECMWF during model event evolution
- Temperature, humidity, winds and surface pressure variables are nudged

# Experiments

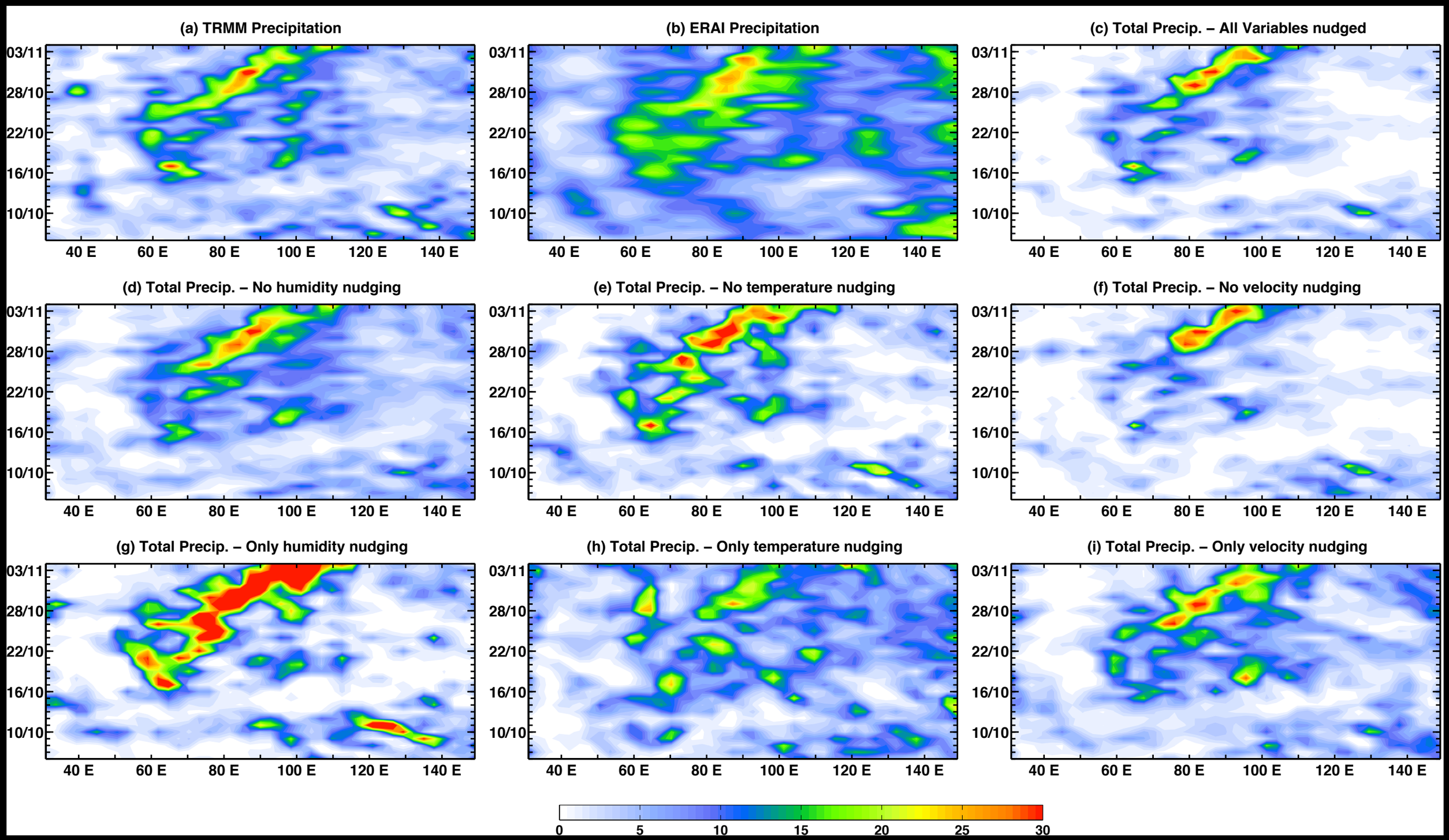
| | |
|---|---|
| ALLVAR | All variables nudged (Q, T, U, V, PS) |
| NOHUM | Humidity not nudged |
| NOTEMP | Temperature not nudged |
| NOVEL | Velocity not nudged |
| ONLYHUM | Humidity only nudged |
| ONLYTEMP | Temperature only nudged |
| ONLYVEL | Velocity only nudged |

# Time series of precipitation



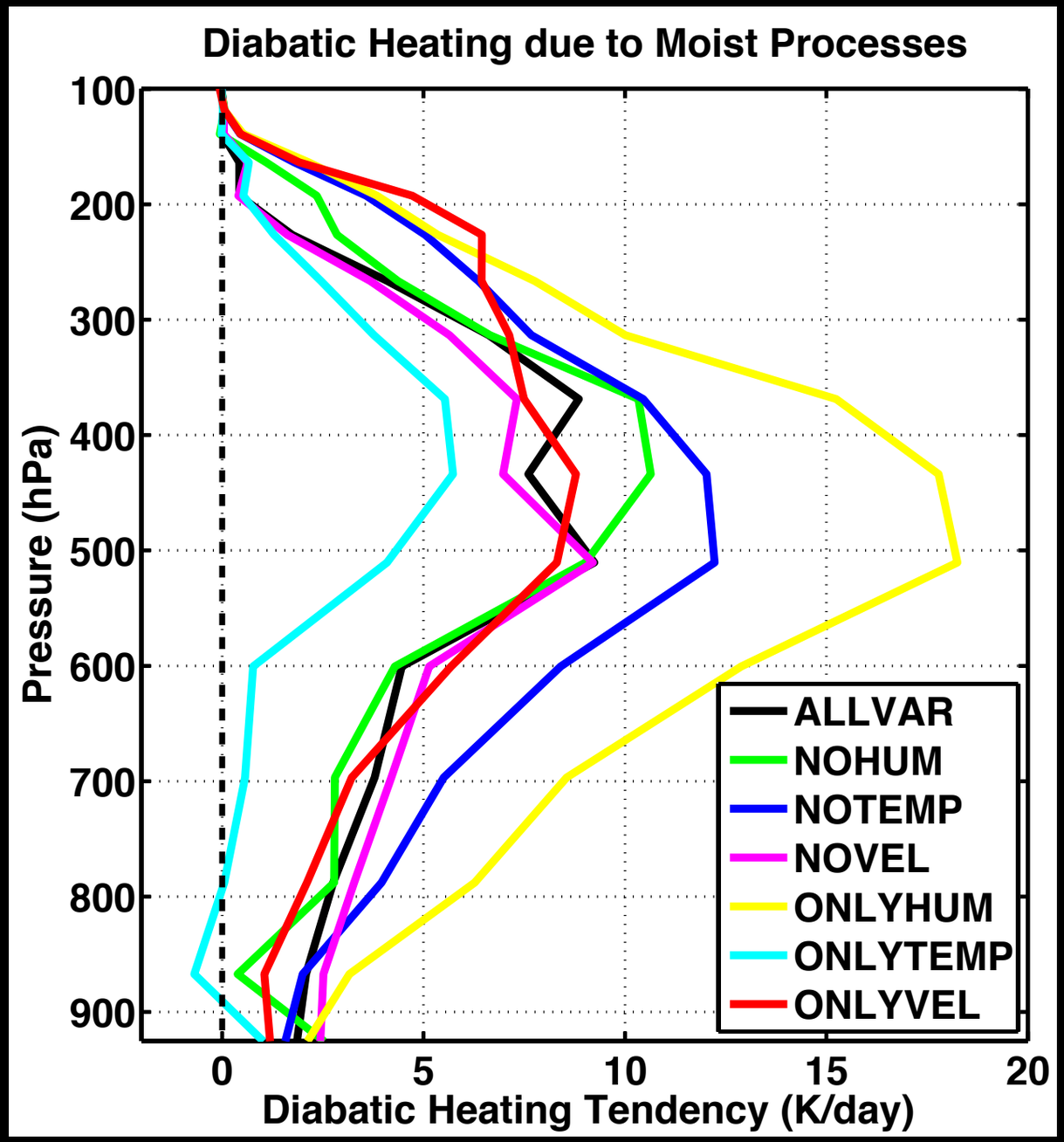

Nudged CAM reproduces TRMM precipitation better than ECMWF

# Total precipitation



# Diabatic heating

## Averaged over NSA region



# Bias detection

Negative of nudging tendency = Model bias

(Model - Reanalysis)/timescale

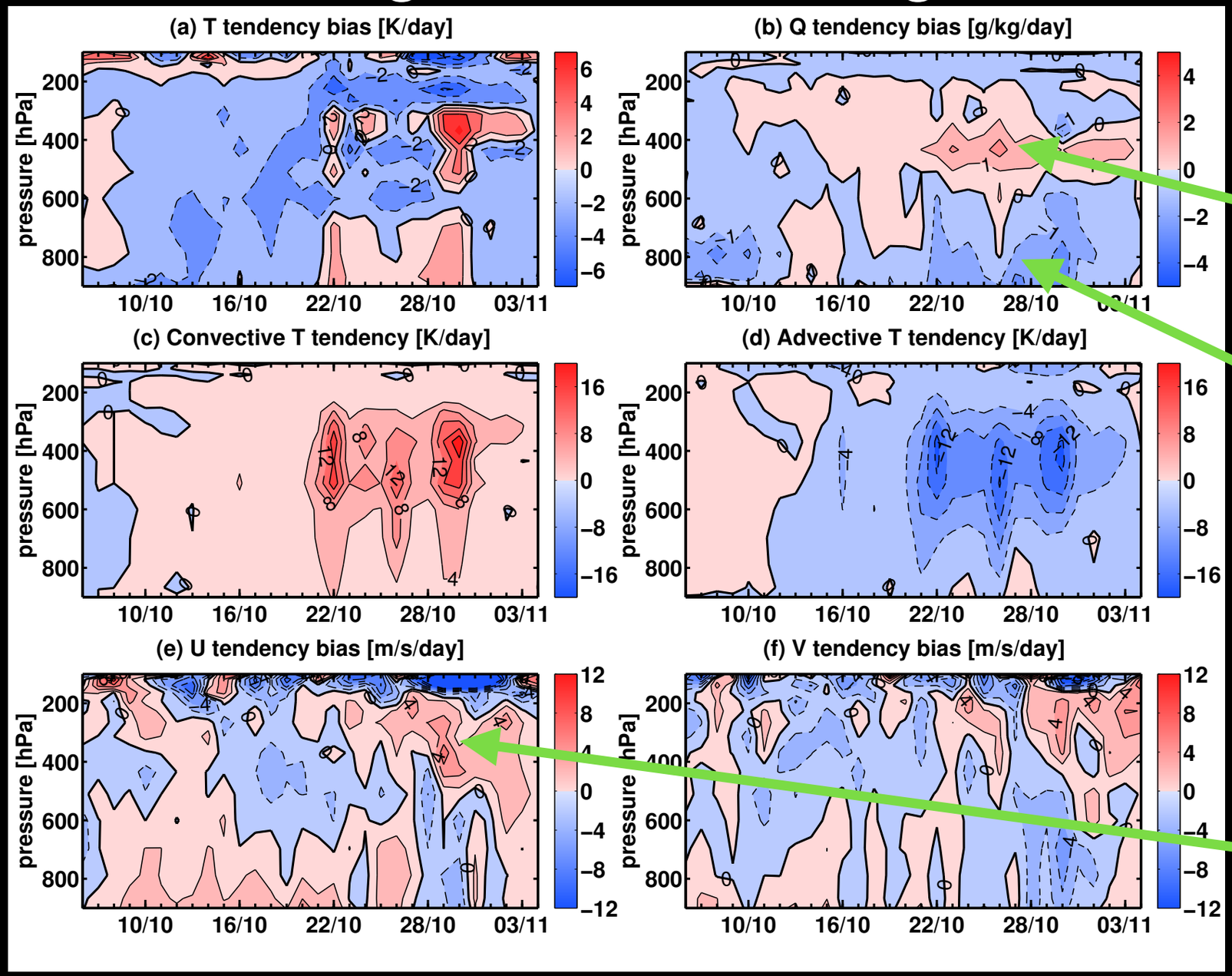
# ALLVAR Nudging tendencies

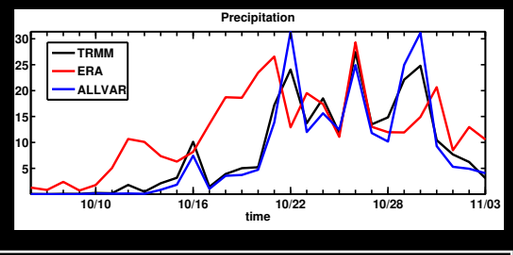
## Averaged over NSA region

T, Q tendency bias

Conv, Adv tendency

U, V tendency bias



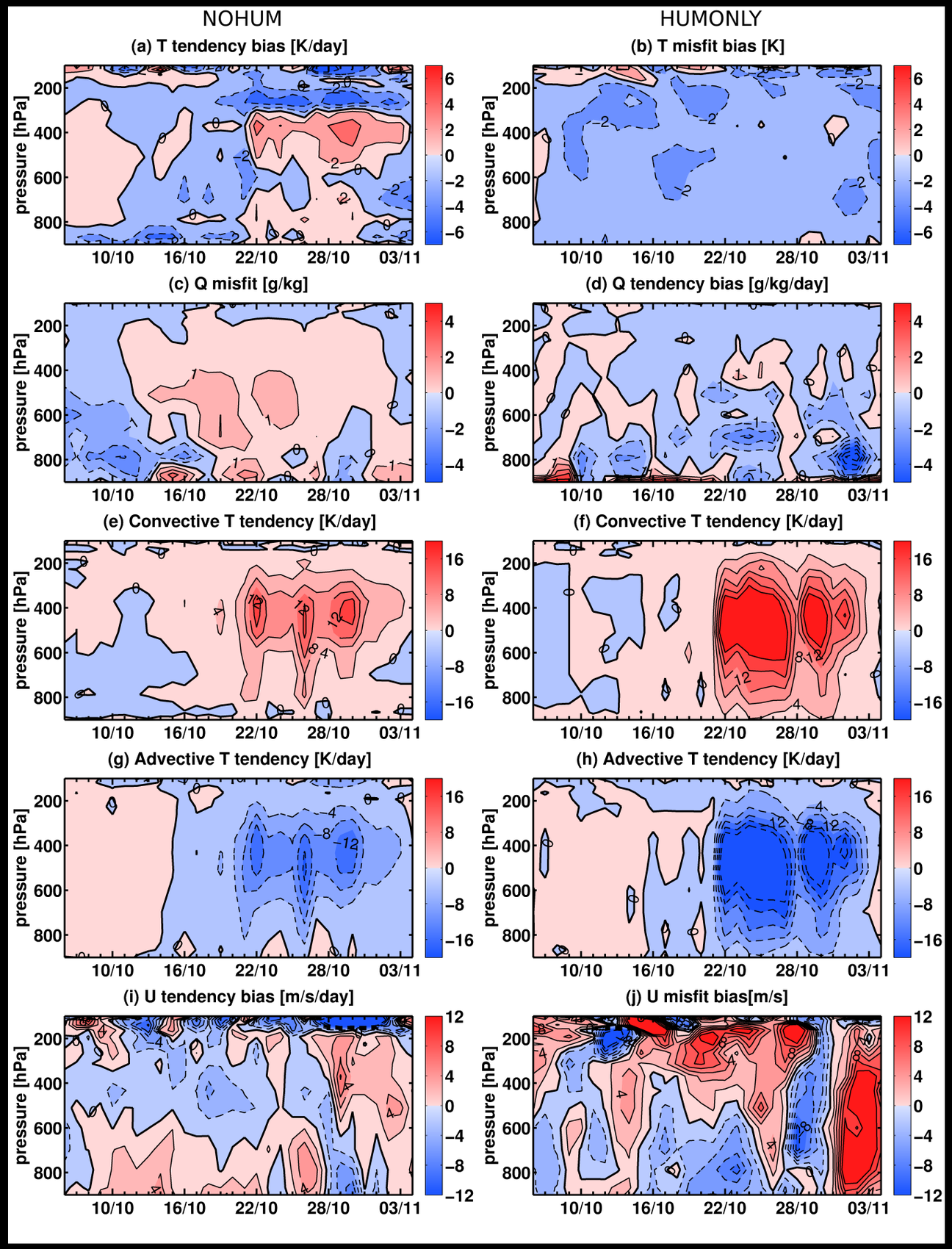




Too little upper level condensation

Too little lower level reevaporation

Too much vert. transport of zonal momentum

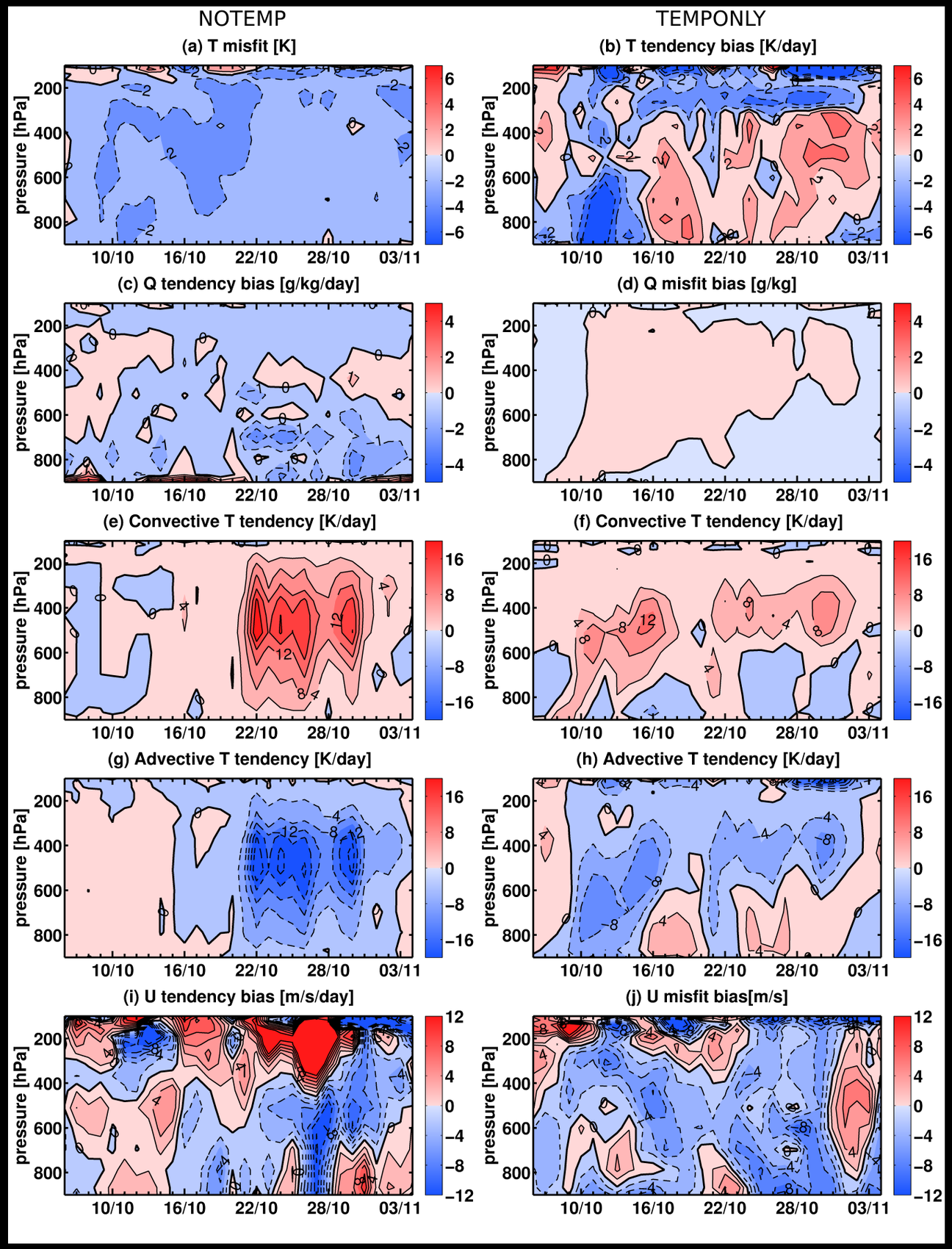
# Humidity Nudging Experiments




No Humidity Nudging tendencies are similar to ALLVAR

If humidity alone is nudged, convection is too strong

# Temperature Nudging Experiments

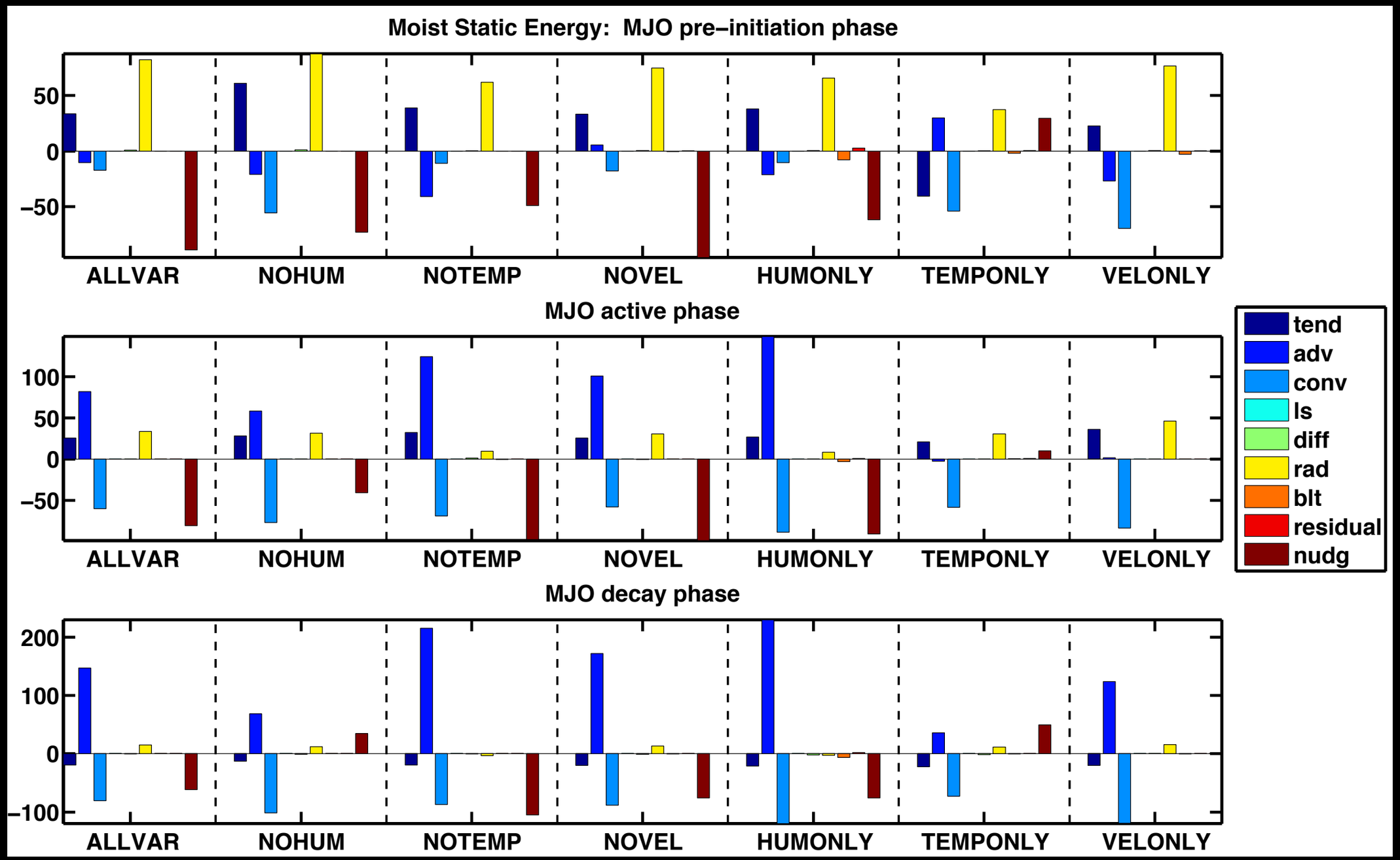



No Temperature Nudging : Atm. is too cold prior to MJO initiation, but humidity biases are small

If temperature alone is nudged, humidity biases are small but convection starts too early.

# MSE Budget (Free Trop.)

$$\underbrace{< h_t >}_{\text{tendency}} = -\underbrace{< v.\nabla h >}_{\text{advection}} + \underbrace{< h_{conv} >}_{\text{convective tendency}} + \underbrace{< h_{ls} >}_{\text{largescale tendency}} + \underbrace{< h_{diff} >}_{\text{diffusive tendency}} + \underbrace{< h_{rad} >}_{\text{radiative tendency}} + \underbrace{< h_{nud} >}_{\text{nudging tendency}}$$



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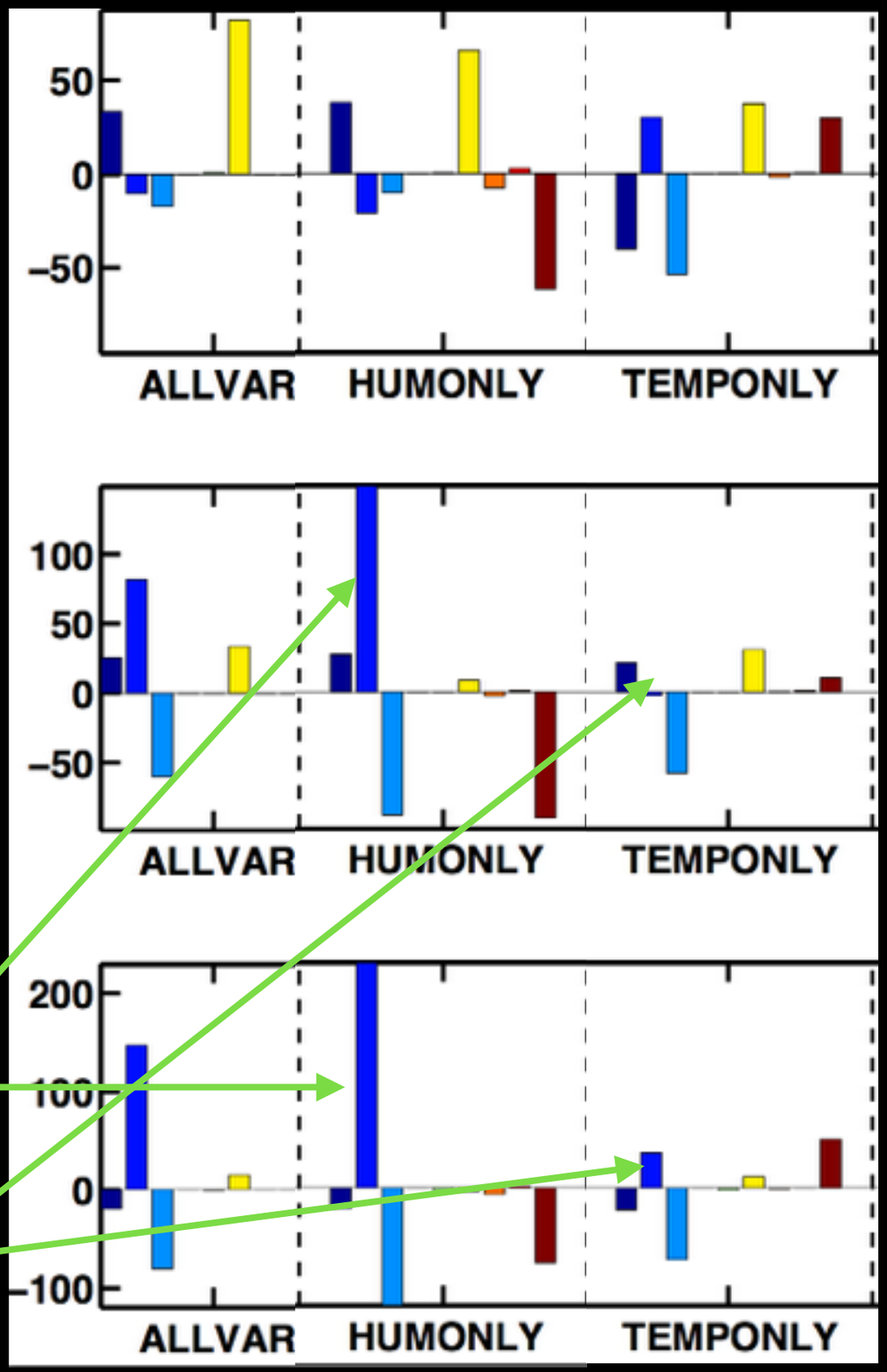


MJO Initiation phase

MJO Mature phase

Adv. acts as MSE source

Not much adv.

MJO Decay phase

# Summary

- The hindcast has a
  - **much faster phase speed**,
  - a **dry relative humidity bias**,
  - a **stronger zonal wind shear** and
  - a **weaker** MJO peak **amplitude**.

- Nudging tendency analysis shows
  - Not enough diabatic heating from convection during the initiation and developing phases of the MJO
  - Not enough stratiform condensation in the upper troposphere and
  - re-evaporation in the lower troposphere during the mature and decay phases
  - Too much down-gradient vertical transport of zonal momentum by convection during the MJO evolution.

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Subramanian, A. C. and G. J. Zhang, 2014: Diagnosing MJO Forecast Biases in NCAR CAM3 Using Nudging During the DYNAMO Field Campaign. JGR-Atmospheres, In press.